Surgical Approaches to the Jugular Foramen: A Comprehensive Review

Christoph J. Griessenauer¹ Benjamin McGrew² Petru Matusz³ Raffaele De Caro⁴ Marios Loukas⁵
R. Shane Tubbs⁶

¹Division of Neurosurgery, Beth Israel Deaconess Medical Center, Harvard University, Boston, MA, United States

²Division of Otolaryngology, Department of Surgery, University of Alabama at Birmingham, AL, United States

³Department of Anatomy, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

⁴Institute of Human Anatomy, Department of Molecular Medicine, University of Padova, Padova, Italy

⁵Department of Anatomical Sciences, School of Medicine, St George's University, Grenada, West Indies

⁶Pediatric Neurosurgery, Children's of Alabama, Birmingham, AL, United States

Address for correspondence Christoph J. Griessenauer, Division of Neurosurgery, Beth Israel Deaconess Medical Center, Harvard University, 110 Francis St., Boston, MA 02215, United States (e-mail: christoph.griessenauer@gmail.com).

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Abstract

Keywords

- jugular foramen
- skull base
- posterior fossa
- neurosurgery

Introduction Multiple surgical approaches and combinations thereof have been described to gain access to the jugular foramen. In an area laden with important neurovascular structures, care must be taken in choosing the best surgical approach for treatment of rare pathologies involving this region.

Methods This manuscript provides a comprehensive review of the relevant anatomy along with an overview of the various approaches to the jugular foramen. In an attempt to simplify the various concepts, we propose a basic distinction into anterolateral and posterolateral approaches based on the main trajectory targeting the jugular foramen.

Conclusion The anatomy surrounding the jugular foramen is exceedingly complex and requires in-depth understanding of skull base and head and neck relationships.

Introduction

The jugular foramen is a canal between the occipital bone and the inferior and medial portions of the petrous pyramid of the temporal bone.^{1–6} Its intracranial aperture courses anterolaterally and inferiorly to the extracranial opening at the skull base and contains the posterolateral pars venosa and anteromedial pars nervosa, partially separated by the jugular spine of the temporal bone and sometimes completely by a fibrous or bony septum.^{1–5,7–9} Traditionally, the pars venosa contains the jugular bulb, from the sigmoid sinus, along with the vagus (X) and spinal accessory nerves (XI) and the posterior meningeal branch of the ascending pharyngeal artery, which runs between cranial nerves X and XI. Conversely, the pars nervosa includes the glossopharyngeal nerve (IX) and the inferior petrosal

sinus.^{1,2,5,6,8,10} The inferior petrosal sinus treks from the cavernous sinus, usually courses between cranial nerve IX and cranial nerves X and XI, and eventually joins the jugular bulb medially.^{2,5,7,10} In addition, the occipital artery gives rise to several meningeal branches that can pass through the pars venosa of the jugular foramen³ (–Fig. 1).

The dura mater covering the intracranial aperture of the jugular foramen contains a posterolateral compartment for the sigmoid sinus, an anteromedial compartment for the inferior petrosal sinus, and a neural compartment for cranial nerves IX, X, and XI.^{3,4,11} The neural compartment forms two perforations, the glossopharyngeal and the vagal meati, that are constantly separated by a dural septum of variable width. The glossopharyngeal nerve passes through the glossopharyngeal meatus that

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Fig. 1 Anatomy of the neurovascular structures of the jugular foramen.

is funnel-shaped, whereas cranial nerves X and XI pass through the vagal meatus that is larger with variable shape.^{3,4,12–18}

Tumors of the Jugular Foramen

Tumors are the most common pathology involving the jugular foramen and include glomus jugulare tumors arising from the chemoreceptor system, schwannomas of the lower cranial nerves, meningiomas, chordomas, chondrosarcomas, and metastatic tumors.¹⁹ Glomus jugulare tumors may arise in the adventitia of the jugular bulb or along the tympanic branch of the glossopharyngeal nerve, or Jacobson nerve, and the auricular branch of the vagus nerve, or Arnold nerve. Tumors of the jugular foramen may be confined to the jugular foramen or extend into the nasopharynx through the eustachian tube, the middle fossa through the tegmen tympani or the petrous carotid canal, into the posterior fossa through the intracranial openings of the jugular foramen, hypoglossal canal, or internal acoustic meatus, or into the neck through the extracranial opening of the jugular foramen.²⁰ The pattern of invasion and destruction of the individual tumor directs the selection of the surgical approach.

Syndromes Involving the Jugular Foramen

Various syndromes due to involvement of variable combinations of neurovascular structures of or related to the jugular foramen have been reported.²¹ The syndrome of the jugular foramen (Vernet syndrome) involves IX, X, and XI, and is characterized by loss of taste in the posterior third of the tongue, paralysis of the vocal cords and palate, and weakness of the trapezius and sternocleidomastoid muscles. In Avellis syndrome, patients experience paralysis of the vocal cords and palate. It may be associated with contralateral dissociate hemianesthesia with loss of pain and temperature sensation due to spinothalamic tract involvement, but preservation of

touch and pressure sensation. Schmidt syndrome is characterized by lesion of the vagal and spinal accessory nuclei or their radicular fibers manifesting with ipsilateral paralysis of the soft palate, pharynx, and larynx, hemianesthesia of the pharynx and larynx, and ipsilateral weakness of the trapezius and sternocleidomastoid muscles. In Tapia syndrome lesions of the motor nuclei or rootlets of X and the hypoglossal nerve (XII) result in ipsilateral paralysis of the pharynx and larynx with ipsilateral paralysis and atrophy of the tongue. Jackson syndrome is produced by a nuclear or radicular lesion of X, XI, and XII, and manifests with ipsilateral paralysis of the soft palate, pharynx, and larynx, with hemianesthesia of the larynx and pharynx, ipsilateral weakness of the trapezius and sternocleidomastoid muscles, and ipsilateral paralysis and atrophy of the tongue. In Collet-Sicard syndrome, IX, X, XI, and XII are involved resulting in loss of taste in the posterior third of the tongue, paralysis of the vocal cords and palate, weakness of the trapezius and sternocleidomastoid muscles, paralysis of the tongue, and hemianesthesia of the palate, pharynx, and larynx. Villaret syndrome manifests similar to Collet-Sicard syndrome with the addition of Horner syndrome.²¹

Operative Approach and Surgical Nuances

As the area of the jugular foramen is compact and laden with important neurovascular structures, care must be taken in choosing the best approach on a case-by-case basis. Multiple approaches, some combined, have been used to approach the jugular foramen. Frequently, only subtle nuances distinguish one approach from another adding to the complexity for proper understanding. In an attempt to simplify the various concepts, we propose a basic distinction into anterolateral and posterolateral approaches based on the main trajectory targeting the jugular foramen (–Table 1). Anterolateral approaches include all approaches and their variations that primarily rely on dissection of structures located in front and lateral to the sigmoid sinus and jugular foramen. Posterolateral approaches gain access to the jugular foramen via structures situated behind and lateral to the jugular foramen.

Anterolateral Approaches

The skin incision for anterolateral approaches is either pre- or retroauricular, and starts above the level of the pinna and

Table 1 Anterolateral and posterolateral approaches to the jugular foramen

Anterolateral	Posterolateral
Postauricular transtemporal approach	Retrosigmoid approach
Preauricular subtemporal-infratemporal approach	Far-lateral approach
	- Transcondylar approach
	- Supracondylar approach
	- Paracondylar approach

Fig. 2 Anterolateral approach. A pre- or, as illustrated here, retroauricular curvilinear skin incision is performed from above the level of the pinna inferiorly into the neck superficial to the sternocleidomastoid muscle. The mastoid process is exposed, the sternocleidomastoid muscle is reflected, and a neck dissection is performed to expose the internal and external carotid artery, the internal jugular vein, and the lower cranial nerves. A mastoidectomy involving primarily the intralabyrinthine region to expose the sigmoid sinus, jugular bulb, and mastoid portion of the facial nerve is completed. The facial nerve is mobilized anteriorly. Resection or mobilization of the temporomandibular joint and condylar process of the mandible along with a frontotemporal craniotomy provide access to the infratemporal fossa.

extends in a curvilinear fashion inferiorly into the neck superficial to the sternocleidomastoid muscle (—Fig. 2).

Postauricular Transtemporal Approach

The key components of the postauricular transtemporal approach are mastoidectomy and neck dissection. Initially a C-shaped retroauricular skin incision is made and the sternocleidomastoid muscle and the posterior belly of the digastric muscle are reflected and a neck dissection is performed to expose the internal and external carotid arteries, the internal jugular vein, and the lower cranial nerves. The mastoidectomy primarily involves the intralabyrinthine region with exposure of the sigmoid sinus, jugular bulb, and mastoid portion of the facial nerve. Hearing does not have to be sacrificed.²² To fully expose the lateral half of the jugular foramen, the mastoid portion of the facial nerve is mobilized anteriorly, the styloid process is resected, and detachment of the rectus capitis lateralis muscle from the jugular process of the occipital bone is performed.²⁰

Preauricular Subtemporal-Infratemporal Approach

This approach provides access to structures located anteriorly to the jugular foramen, and includes the petrous portion of the internal carotid artery, eustachian tube, and petrous apex. A preauricular skin incision extending inferiorly across the zygomatic process of the temporal bone into the cervical region is made. Both the temporalis muscle and zygomatic arch are reflected inferiorly. A frontotemporal craniotomy with or without removal of the superior and lateral orbital rim is performed. Removal or inferior mobilization of the temporomandibular joint and condylar process of the mandible allow access to the floor of the middle cranial fossa. The middle cranial fossa floor is removed from lateral to medial until the carotid canal is reached. Both the eustachian tube and tensor tympani muscle, coursing parallel to the petrous carotid artery, are sacrificed. Removal of the styloid process allows anterior mobilization of the internal carotid artery and access to the clivus. Drilling of Kawase's triangle gains access to the posterior cranial fossa.²⁰

An early description of the preauricular subtemporal-infratemporal approach was provided by Fisch in 1978.²³ Fisch reported three types of infratemporal fossa approaches to the lateral skull base. Type A allows access to the temporal bone in its infralabyrinthine and apical compartments, and is suitable for tumors of the jugular foramen among others. As opposed to Rhoton's description of this approach, Fisch performed a retroauricular skin incision. The external auditory canal is transected at the bone-cartilage junction and closed as a blind sac. Neck dissection allows for identification

Fig. 3 Anatomy of the neurovascular structures of the jugular foramen as seen with an infratemporal fossa approach.

of the peripheral facial nerve distal to the stylomastoid foramen, the extracranial portions of the lower cranial nerves, the carotid arteries, and internal jugular vein (►Fig. 3). This is followed by radical mastoidectomy and subtotal petrosectomy, including the removal of the osseous external auditory canal, tympanic membrane, and ossicles. The facial nerve is isolated from the geniculate ganglion to the stylomastoid foramen and transposed anteriorly. Both middle and posterior cranial fossa dura in front (Trautmann's triangle) and behind of the sigmoid sinus are exposed.²⁴ The petrous internal carotid artery is identified and the eustachian tube is obliterated at its bony isthmus. The mandibular condyle is resected, and the temporal root of the zygoma and lateral orbital rim are removed for additional exposure. This approach provides excellent exposure of the jugular foramen, intrapetrous carotid artery, and lateral skull base.²⁵

Posterolateral Approaches

The skin incision for posterolateral approaches to the jugular foramen frequently assumes the shape of a hockey stick starting posteriorly and superiorly to the pinna following

Fig. 4 Posterolateral approach. A skin incision in shape of a hockey stick starting posteriorly and superiorly to the pinna following the superior nuchal line to the midline extending inferiorly in the midline to the spinous process of C2 is performed. The C1 hemiarch and the occipital bone inferiorly to the transverse and sigmoid sinus are removed. The vertebral artery is isolated and reflected inferiorly after opening of the posterior aspect of the C1 foramen transversarium. The jugular foramen is opened through a supra- and paracondylar approach. A partial transcondylar exposure is performed to preserve the atlanto-occipital joint. The jugular tubercle is the posterior boundary of the jugular foramen separating it from the hypoglossal canal.

the superior nuchal line to the midline where it makes a right-angle turn and extends inferiorly in the midline to the spinous process of C2 (►Fig. 4).

Retrosigmoid Approach

The retrosigmoid approach is accomplished by a C-shaped skin incision posterior and parallel to the outline of the pinna and a lateral, suboccipital craniotomy or craniectomy exposing the dura inferior and posterior to the transverse and sigmoid sinuses, respectively. The dura is opened and the cerebellum is gently elevated away from the posterior surface of the temporal bone. The lateral aspect of the brain stem and intracranial portions of the cranial nerves exiting through the internal acoustic meatus and jugular foramen become visible. This approach is suitable for primarily intradural pathologies.

Far-Lateral Approach

The far-lateral approach consists of a skin incision in shape of a hockey stick starting at the mastoid tip, running posteriorly to theinion, and inferiorly to the spinous process of C2. The muscles attaching to the occipital bone are detached en block and reflected inferiorly. Removal of the posterior arch or hemiarch is performed, and the occipital bone inferiorly to the transverse and sigmoid sinuses is removed. The vertebral artery can be isolated and reflected inferiorly after opening of the posterior aspect of the C1 foramen transversarium. The jugular foramen is opened from posterior by one of three ways or a combination thereof and provides access to the jugular foramen, lower clivus, and premedullary area.

The transcondylar approach opens the jugular foramen by removal of portions of the occipital condyle, and can be categorized into an atlanto-occipital transarticular approach where parts of the occipital condyle and superior facet of C1 are removed and the occipital transcondylar variant that is directed above the atlanto-occipital joint through the occipital condyle and below the hypoglossal canal.²⁰

The supracondylar approach is accomplished by drilling the occipital bone above and behind the occipital condyle that includes the condylar fossa. The condylar fossa forms the external occipital surface of the jugular tubercle, a rounded superior projection of the internal surface of the condylar portion of the occipital bone that forms the roof of the hypoglossal canal, and has shallow impressions for cranial nerves IX, X, and XI as they course to the jugular foramen. The fossa is limited laterally by the sigmoid sulcus and the jugular foramen. The supracondylar approach can be directed to the hypoglossal canal and may include removal of the jugular tubercle to visualize the area in front of the brain stem.²⁰

The paracondylar approach relies on drilling of jugular process of the occipital bone, the attachment for the rectus capitis lateralis muscle, lateral to the occipital condyle, and provides access to the posterior portion of the jugular foramen and to the mastoid on the lateral side of the jugular foramen.²⁶

Variations and combinations of these approaches are numerous with a variety of different terms used characterize

them.^{27–36} Regardless of the terminology, the focus is lateral suboccipital craniotomy and removal of the bone in the region of the occipital condyle.^{28–31}

The main indications for juxtacondylar approaches are neurinomas and meningiomas of the jugular foramen and for tumors such as paragangliomas that extend into the petrous bone.³⁷

Conclusion

Multiple approaches, some combined, have been described to approach the jugular foramen. Frequently, only subtle nuances distinguish one approach from another. In an attempt to simplify the various concepts, we propose a basic distinction into anterolateral and posterolateral approaches based on the main trajectory targeting the jugular foramen. Anterolateral approaches include all approaches and their variations that primarily rely on dissection of structures located in front and lateral to the sigmoid sinus and jugular foramen. Posterolateral approaches gain access to the jugular foramen via structures situated behind and lateral to the jugular foramen.

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